LEVEL

AD A089612

# ANALYSIS OF MANUAL THREAT EVALUATION AND WEAPONS ASSIGNMENT (TEWA) IN THE AN/TSQ-73 AIR DEFENSE SYSTEM

Charles C. Jorgensen and Michael H. Strub

ARI FIELD UNIT AT FORT BLISS, TEXAS

DTIC
SELECTED
SEP 2 6 1980

A

ari

U. S. Army

Research Institute for the Behavioral and Social Sciences

October 1979

DDC FILE COPY

80 9 25 064

# U. S. ARMY RESEARCH INSTITUTE

# FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the
Deputy Chief of Staff for Personnel

JOSEPH ZEIDNER
Technical Director

FRANKLIN A. HART
Colonel,    US Army
Commander

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

| REPORT DOCUMENTATION PAGE | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|

| 1. REPORT NUMBER | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
|---|---|---|
| Technical Report 419 | AD-A089 672 | |

| 4. TITLE *(and Subtitle)* | 5. TYPE OF REPORT & PERIOD COVERED |
|---|---|
| ANALYSIS OF MANUAL THREAT EVALUATION AND WEAPONS ASSIGNMENT (TEWA) IN THE AN/TSQ-73 AIR DEFENSE SYSTEM | Technical rept. |
| | 6. PERFORMING ORG. REPORT NUMBER -- |

| 7. AUTHOR(s) | 8. CONTRACT OR GRANT NUMBER(s) |
|---|---|
| Charles C. Jorgensen and Michael H. Strub | -- |

| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
|---|---|
| U.S. Army Research Institute for the Behavioral and Social Sciences (PERI-IB) 5001 Eisenhower Avenue, Alexandria, VA 22333 | 2Q762722A765 |

| 11. CONTROLLING OFFICE NAME AND ADDRESS | 12. REPORT DATE |
|---|---|
| U.S. Army Air Defense School Fort Bliss, TX 79916 | October 1979 |
| | 13. NUMBER OF PAGES 23 |

| 14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)* | 15. SECURITY CLASS. *(of this report)* |
|---|---|
| ARI-TR-419 | Unclassified |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE -- |

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

--

18. SUPPLEMENTARY NOTES

--

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Air defense systems
Human factors
Manual weapons assignment
Manual threat evaluation

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

As tactical air threats have increased, so has the need to efficiently coordinate ground defense. With the advent of computer aided command and control systems, the identification of human strengths and limitations has become critical to the success of the Army air defense mission.

The research reported in this paper was conducted in 1975 during the early development of the AN/TSQ-73 missile minder. The missile minder is

(Continue)

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

i SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

408010

Item 20 (Continued)

representative of a class cf emerging air defense systems which place unusual demands on the processing capabilities of the human operator. The purpose of the research was to evaluate human operator performance under realistic task loading, aircraft threats, and manning configurations. As a result of this study, procedures were developed which can effectively be applied to assess operator performance under a wide variety of emerging air defense systems. The procedure can also be utilized to aid in firing doctrine development, assist human factors specification, and improve interoperability decisions in linked air defense systems.

# ANAYLSIS OF MANUAL THREAT EVALUATION AND WEAPONS ASSIGNMENT (TEWA) IN THE AN/TSQ-73 AIR DEFENSE SYSTEM

Charles C. Jorgensen and Michael H. Strub

Submitted by:
Michael H. Strub, Chief
ARI FIELD UNIT AT FORT BLISS, TEXAS

## FOREWORD

The Army Research Institute Field Unit at Fort Bliss is actively engaged in a research program designed to improve the evaluation of human performance in air defense systems. As tactical air threats have increased, so has the need to efficiently coordinate ground defense. With the advent of computer-aided command and control systems, the identification of human strengths and limitations has become critical to the success of the Army air defense mission.

The research reported in this paper was conducted in 1975 during the early development of the AN/TSQ-73 missile minder. The missile minder represents a class of emerging air defense systems which place unusual demands on the processing capabilities of the human operator. The purpose of the research was to evaluate human operator performance under realistic task loading, aircraft threats, and manning configurations. As a result of this study, procedures were developed which can effectively be applied to assess operator performance under a wide variety of emerging air defense systems. The procedure can also be utilized to help develop firing doctrine, assist human factors specification, and improve interoperability decisions in linked air defense systems. This research is in response to requirements of Army project 2Q762722A765 and special needs of the U.S. Army Air Defense School (USAADS), Fort Bliss, Tex.

JOSEPH ZEIDNER
Technical Director

Analysis of Manual Threat Evaluation and Weapons Assignment in the AN/TSQ-73 Air Defense System

## BRIEF

Requirement:

To investigate human performance under varying air defense threats.

To determine human overload points requiring transition from manual to automatic operational modes.

Procedure:

Air defense crews were evaluated over a six-day period under changing conditions of crew configuration, number of available fire units, and attacking aircraft threat. Switch action times were recorded by the AN/TSQ-73 computer and matched against event times in predetermined threat scenarios. Analysis of operator actions utilized switch actuation latencies and operator errors (identified via incorrect switch sequences). Results were subjected to advanced multiple regression analysis modeling in order to generate predictive formulas for operator performance under load.

Findings:

Hostile aircraft engagement latency averaged 3.47 minutes for system contact, identification, and weapon assignment during the simulated combat exercise. The chances were at least 50 percent that the aircraft would complete its run if it was in a major assault wave. A manning configuration in which the officer implements decisions directly through the weapon assignment console significantly improves assignment times. Wave size of aircraft had the greatest effect on the weapon assignment operator although the aircraft identification operator times increased linearly as a function of the number of aircraft. Manual weapon assignment operators tended to overload at eight aircraft and reaction times increased rapidly. Greater numbers of fire units improved weapon assignment times but only if eight or more were available. Operator fatigue may be a significant factor in weapon assignment under heavy task demands.

Utilization:

The techniques developed in this report can be applied in any air defense system having built in microprocessors that can record operator switch actions, such as the developing PATRIOT system. The resulting improved estimates of operator actions and reaction times can be applied to firing doctrine evaluation, system software development, the man/machine interface, and interoperability studies involved in linking together command and control systems.

# TABLE OF CONTENTS

## LIST OF TABLES AND FIGURES

# I. INTRODUCTION

The Army is fielding a new air defense system for command and control of Hawk and Hercules Fire Units. Called the AN/TSQ-73 (Missile Minder), the system contains software which will automatically perform threat evaluations and weapon assignment (TEWA). The chief advantage of the automatic TEWA is its speed in assigning hostile aircraft to available fire units. Given sufficient time, it is likely that the tactical director, by virtue of being able to take into account complex information and recognize event patterns, would make more "intelligent" TEWA than the machine since the machine TEWA is software limited.

The tactical director performing manual TEWA is subject to increased information loading and stress as the number of aircraft in an attacking wave increases. The present research sought to investigate human TEWA as a function of wave size to assist in the determination of a manual saturation point. Such a point would suggest the level at which the system should transition from manual/semi-automatic control to automatic control as the intensity of a battle increases and the number of radar tasks become too numerous for manual weapons assignment. While some argue for exclusive manual/semi-automatic mode operation and others for an all automatic mode, it is more likely that the system will reside in the manual/ semi-automatic mode until the operators and tactical directors are overloaded by the sheer volume of tracks requiring attention. At this point, the operators and tactical directors would transfer the system to the automatic mode but still maintain constant monitoring and override capabilities.

The purpose of this experiment was to collect baseline data from which overload points could be determined. It was judged that such points would be a function of the number of hostile aircraft in an attacking wave or scenario, the number of fire units under direct control of the Q-73, and the rate at which the attacking wave approaches. The first two variables were systematically changed in the experiment, while the third was fixed. Also, a key command and control question concerned whether the tactical director could coordinate activities better from behind the console operators or at the weapons assignment console where he could implement his fire unit assignment decisions directly through the console. Thus, the third primary variable in the experiment was the manning configuration. In one configuration the officer was behind the console operators, while in the second configuration the tactical director sat at the weapons assignment console. Also included for control purposes were three minor variables. They were the specific raid scenario, the test day, and the crew.

## II. PROCEDURE

Personnel participating in the experiment (crews) consisted of
three Air Defense officers and six enlisted men from the US Army Air
Defense School (USAADS) recently detailed to Ft MacArthur, CA, in
connection with the TACS/TADS effort in 1975.  (Pilot data were collected
from an "expert" team of one officer and two enlisted men who had been
assigned to the TACS/TADS project for over a year.)  While the crews did
not receive a formal training program on the AN/TSQ-73, their arrival at
the testing site approximately three weeks prior to the start of the
experiment allowed sufficient time for them to become familiar with the
functions and operations which would be required of them in the experiment.
Although some practice effects were expected to be found over the six
experimental sessions, all crews were judged to be qualified for operating
in the Q-73 at the start of the experiment.

The testing environment consisted of the interior of a prototype
Q-73 van.  The principal items of equipment were two operator consoles,
identical in configuration, which were placed side by side at the front
of the van.  The console on the left side was used for track identifica-
tions and the right console for weapon assignments.  Other equipment
included communication lines for cross talk between the simulated Group
73 and Battalion 73, and between the Battalion 73 and the fire units.
An officer from USAADS served as Group 73 and issued directives to the
Battalion 73 as required.  Four experimenters rotated in the role of
simulating "Squawk" from the fire units, e.g., acknowledgment of assign-
ment, etc.

3

Data collection occurred during six consecutive evenings between 2200 and 0600 as shown at the bottom of Figure 1. Data was collected for the expert team on the morning of the seventh day between 0600 and 0800. Each team served for a two-hour period each evening. Each period consisted of two one-hour sessions. (Simulation equipment constraints precluded simulated raid tapes from being over one hour in length.)

USAADS prepared scenarios from which two raids were scripted and two raid tapes were developed for use in the Q-73's simulation mode of operation. To assure comparable group data, all video viewed by operators on their radar screens was generated from the tapes rather than from live radar signals. The simulation package also included the capability for periodic recordings of the status of all actions taken by the operators and the times of these actions. In addition, the system periodically recorded the status of all fire units under control of the Battalion Q-73.

During each one-hour session, a team would be exposed to three different assaults or waves of varying size. As soon as an aircraft track entered the system and three simulated radar sweeps verified its presence, the track became available to the ID operator seated at the left console. All tracks entered with an unknown identity. Simulated messages into the Q-73 resulted in change of status symbols replacing unknown symbols on the operator's screen. When the ID operator observed this special symbol, he "hooked" the track by placing his cursor over the symbol and pressing the appropriate function switches to reveal whether the track was friendly or hostile.

4

| Crew | Fire Units | Off at Console | | Crew | Fire Units | Off at Console | | Crew | Fire Units | Off at Console | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4 | Yes | | 2 | 4 | No | | 3 | 4 | Yes | Day 1 |
| 2 | 6 | No | | 3 | 6 | Yes | | 1 | 5 | No | Day 2 |
| 3 | 8 | Yes | | 1 | 8 | No | | 2 | 8 | Yes | Day 3 |
| 1 | 8 | No | | 2 | 8 | Yes | | 3 | 8 | No | Day 4 |
| 2 | 6 | Yes | | 3 | 6 | No | | 1 | 6 | Yes | Day 5 |
| 3 | 4 | No | | 1 | 4 | Yes | | 2 | 4 | No | Day 6 |
| 2200 - 2400 | | | | 0100 - 0300 | | | | 0400 - 0700 | | | |

Figure 1. Experimental Design

When a track symbol changed to hostile, it became the duty of the weapons assignment officer to select a fire unit to engage the track. The Q-73 system has limited software to provide automatic assignment of fire units, but it was the purpose of the present experiment to assess human performance capabilities in the manual weapon assignment mode.

For each two-hour session, there were either four, six, or eight fire units under control of the Q-73 (see Figure 1). The manning configuration consisted of having the tactical director behind the console operators or seated at the weapons assignment console. Thus, each combination of fire unit number and manning configuration resulted in six different conditions constituting the six experimental sessions.

# III. RESULTS AND DISCUSSIONS

The analyzed data consisted of 383 sets of reaction times corres-
ponding to complete actions taken by AN/TSQ-73 operators on hostile
aircraft during days 1 through 6. Thirty-three additional sets of times
were obtained from the expert group and were used in non-parametric
analysis of operator training and familiarization. Each set was composed
of three values for a given hostile aircraft: (1) the total time to identify
an aircraft and assign a firing unit; (2) the proportion of the time required
by the ID operator; and (3) the proportion of the time required by the
weapons assignment operator. As an estimate of terminal system effective-
ness, percentages of successfully engaged aircraft were tabulated for
days 5 and 6. A breakdown of these percentages into detailed categories
of actions, e.g., number of friendly aircraft incorrectly engaged, was
precluded due to extraneou  factors such as uncontrolled instructions to
the operators, system problems, and errors on the radar track tapes. It
was still possible, however, to estimate overall performance against
hostile aircraft. These percentages are reported in Table 1.

This Table shows the percentage effectiveness of the operators. It
is based on ratio of the average number of completed identification/
weapon-assignment sequences to the average number of completed identifica-
tions in a wave. Effectiveness remains at about 70% for low- and medium-
size waves. It drops to about 49% for high-wave sizes. In this experiment
a high-wave size was 25 or more aircraft. It is possible that these
estimates may be conservatively low. Effectively completed sequences

TABLE 1.

ACCURACY DATA (DAYS 5 & 6)

| WAVE SIZE | AVERAGE # OF ATTACKING AIRCRAFT | AVERAGE # OF COMPLETED SEQUENCES | PERCENTAGE EFFECTIVENESS |
|---|---|---|---|
| LOW | 7.8 | 5.5 | 70% |
| MEDIUM | 14.9 | 10.3 | 69% |
| HIGH | 22.8 | 11.2 | 49% |
| TOTAL | 15.2 | 9.0 | 60% |

may have been restricted by uncontrolled instructions issued during the experiment to reduce extraneous noise on the operators' screens, such as bogus track identifiers created by rapidly turning aircraft.

A detailed investigation of operator reaction times added insight into the variables influencing overall effectiveness. By examining operators' switch actions on the AN/TSQ-73 console, it was possible to accurately determine ID and weapon assignment times. These times were analyzed in relation to the experimental variables of manning configuration, number of fire units, number of aircraft in an attacking wave, training group, day of test, and raid-tape scenarios. To maximally explore the relationships present in the data, times were subjected to multiple linear regression analysis using an IBM 360-65 computer. The data were tested against 90 different models corresponding to plausible psychological outcomes. Multiple F-tests were then used to choose the most parsimonious models with the greatest degree of explained variance.[1]

The following conclusions were supported by reaction time data. The average total time to identify and successfully engage a hostile aircraft was 208 seconds. (Start time was estimated at about 24 seconds after the system first contacted the radar track.) The average time to correctly

---

[1]It should be noted that the degrees of freedom used in these F statistics represent model comparisons and are not always directly related to the number of experimental variables as is the case in the usual ANOVA Table. The reader is referred to the appendix for reference detailing this procedure.

identify a friendly aircraft was 57 seconds. The ID and weapons assign-
ment (WA) operators did not always respond in the same manner to the
experimental variables. Manning configuration had a significant effect on
WA reaction times ($F_{(1,318)}=9.49$ P<.01). When the officer implemented
decisions through the console his mean reaction time was 91.6 seconds
versus 131.4 seconds when he served as tactical director. This was an
average improvement of 39.8 seconds, or about 30%.

Number of fire units also effected WA time ($F_{2,380}=4.14$ P<.05).
Reaction times were approximately equal for four or six fire units
($\overline{X}_4=116$ seconds versus $X_6=114$ seconds). Eight fire units reduced the
average WA times to $\overline{X}_8=69$ seconds. Caution should be used in interpreting
this result however. The percentage of explained variation due to fire
units was low ($M^2=.0213$ where $M^2$ is squared multiple correlation
coefficient of the fire unit variable) which means that although the
effect was statistically significant, number of fire units contributed
little to overall prediction of reaction time. Increased numbers of
fire units may improve overall effectiveness as well, but due to a lack of
usable performance data, this question could not be answered.

The most powerful predictive variable was wave size. The most
efficient predictive model was a linear function of ID ($F_{(1,381)}=7.22$ P<.001)
and a cubic function of WA ($F_{2,380}=8.06$ P<.001). Least squares fitting
of alternate models show ID is best fit by the linear function:

$$RT_{ID}=60.3 + 2.05W$$

where W is the number of aircraft in the attacking wave. Actual mean

values for ID times are plotted in Figure 2 as a function of wave size. For WA the linear trend seen in ID times was not evident. Figure 3 shows mean reaction times already rising rapidly at eight aircraft, suggesting that the WA operator was already overloaded. Latencies reach a peak of 176 seconds per aircraft at 16 aircraft and recede to a steady state level of 100 seconds thereafter. Though dropping from the highest value, terminal WA times are still well over a minute longer per aircraft than at a wave size of eight. This decrease coincides with a loss in overall effectiveness and may be due to the forced adoption of faster but less optimal WA strategies for assigning hostile targets to the most appropriate fire units. Comparisons between possible wave models showed the WA data was best fit by a cubic equation:

$$RT_{WA} = 13.23w - .012w^3 - 29.37$$

The cubic fit was a significantly better predictor than either a linear or a second order equation ($F_{(1,380)} = 4.29$, $P < .05$).

An overall best equation for estimating total reaction time is the sum of the optimal ID and WA equations:

$$RT_{TOT} = 30.93 + 15.28w - .012w^3.$$

The mean RTs for the total data are shown in Figure 4 along with the predictive curve generated by the above formula.

Analysis of the variables of days and raid tapes generated new research questions. Times from two raid tapes showed no difference for ID ($F_{(1,381)} = 2.18$ $P > .20$) but a significant difference for WA ($F_{(1,381)} = 9.05$ $P < .005$). This could imply that the WA task is

more sensitive to the attack configuration than the ID task, since the raid tapes generated different numbers of artificial tracks on the radar screens depending on the aircraft maneuvers utilized in the raid.

Reaction time data show a significant effect over days on ID and WA times ($F_{ID}(5,377)=2.59$ P<.25, $F_{WA}(5,377)=5.64$ P<.001). Times over days were best fit by simple linear functions which are plotted in Figures 5 and 6.

$$RT_{ID}=149.66-13.14d$$

$$RT_{WA}=32.97+19.87d$$

where d is the day's number d $\epsilon$ {1, 2, 3, 4, 5, 6}. The most interesting fact about these data is that ID and WA functions had opposite slopes. The negative slope of the ID function means RT decreased over days for the ID operator. The positive slope for WA showed just the opposite effect. The interpretation of this finding is difficult. One possible explanation could be that the WA task is more fatiguing to the operator and increased latency due to fatigue obscured normal improvement resulting from practice effects. If this is the case, it implies that WA operator fatigue during combat could markedly increase response times. To more fully investigate repetition effects, an additional analysis was conducted using the 33 time sets from the expert group. Since the expert group participated only during one special session of the experiment but were still highly trained, it was felt that their performance could reflect ID and WA training effects without experiment fatigue. Expert times were paired with mean times from the experimental groups on days 5 and 6 on the basis of aircraft simulation numbers coded into the raid tapes.

Due to the low number of expert scores and the possible violation of normality assumptions, a non-parametric Wilcoxen matched pairs signed-ranks test was chosen. The results showed no significant difference for ID times ($Z=1.03$ $p<.15$), but faster weapons assignment times for the expert group ($Z=3.39$, $p<.01$). Mean WA time for experts was 62.6 versus 82.0 seconds for days 5 and 6. This difference could still represent only greater familiarity with the Q-73 operating system. Such a possibility receives support from the experts greater use of system switch options as well as superior ability to handle extraneous verbal "squawk" evidenced on tape recordings made of the sessions. However, it could also be a result of fatigue differences. Additional research could provide the answer by testing the issue directly.

## IV. CONCLUSIONS

Tentative conclusions may be drawn for some of the original research questions. First, TEWA in the semi-automatic mode is not instantaneous. Average time for system contact, identification, and weapons assignment in the AN/TSQ-73 system was 3.47 minutes. Second, manning configuration in which the officer implements decisions directly through the WA console significantly improves assignment times. Third, wave size has its greatest effect on the WA operator, although ID times do increase linearly as the number of aircraft increase. Fourth, WA is overloading at eight aircraft and reaction times increase rapidly. Increased numbers of fire units do improve WA times but only if eight or more are available. Finally, operator fatigue could be a consideration in WA under heavy task demands.

REFERENCES

Ward, Joe H. and Jennings, Earl, Introduction to Linear Models, 1973, Prentice-Hall, Inc.
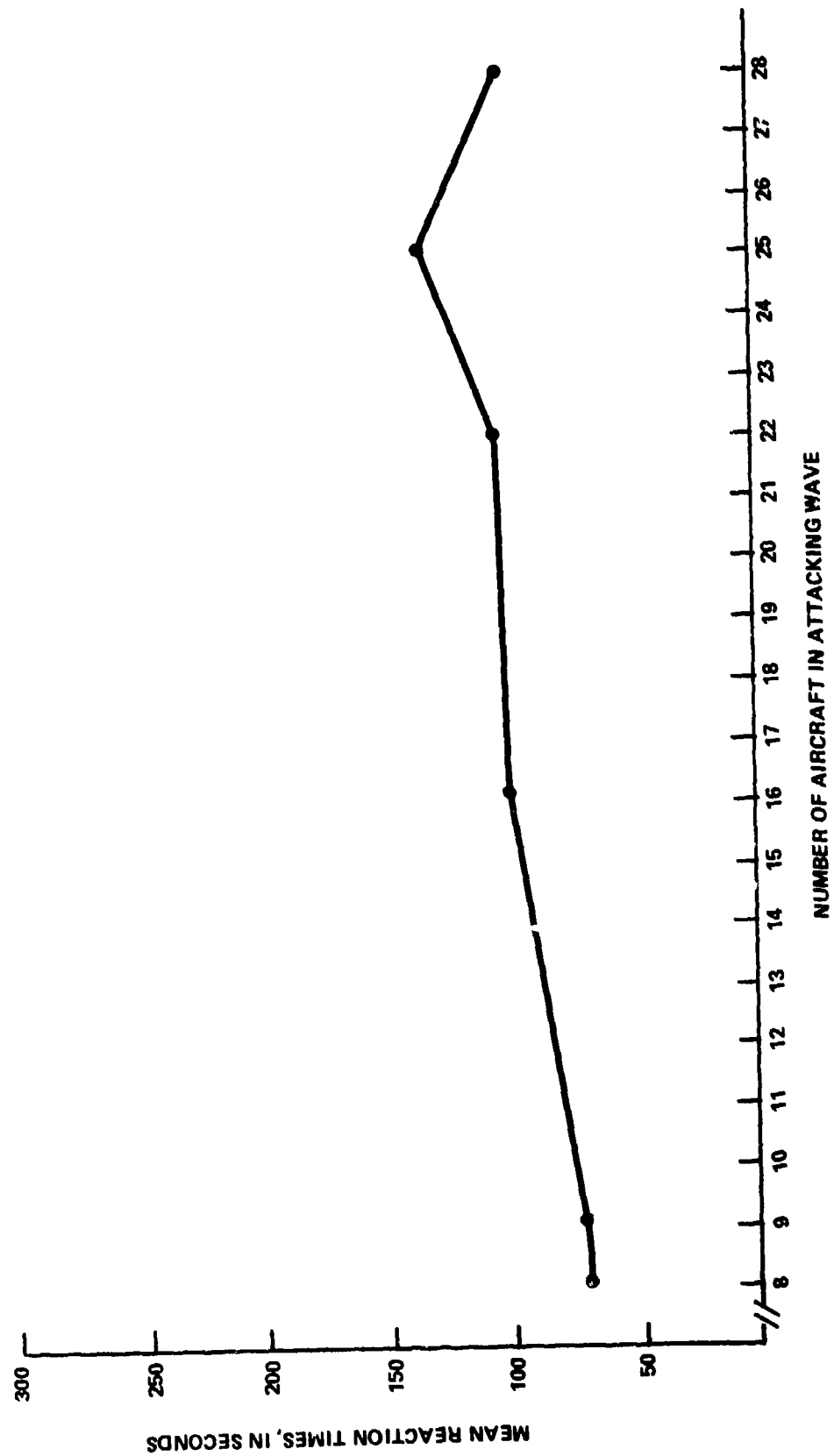
Figure 2. Mean reaction times for ID as a function of six wave sizes.

NUMBER OF AIRCRAFT IN ATTACKING WAVE
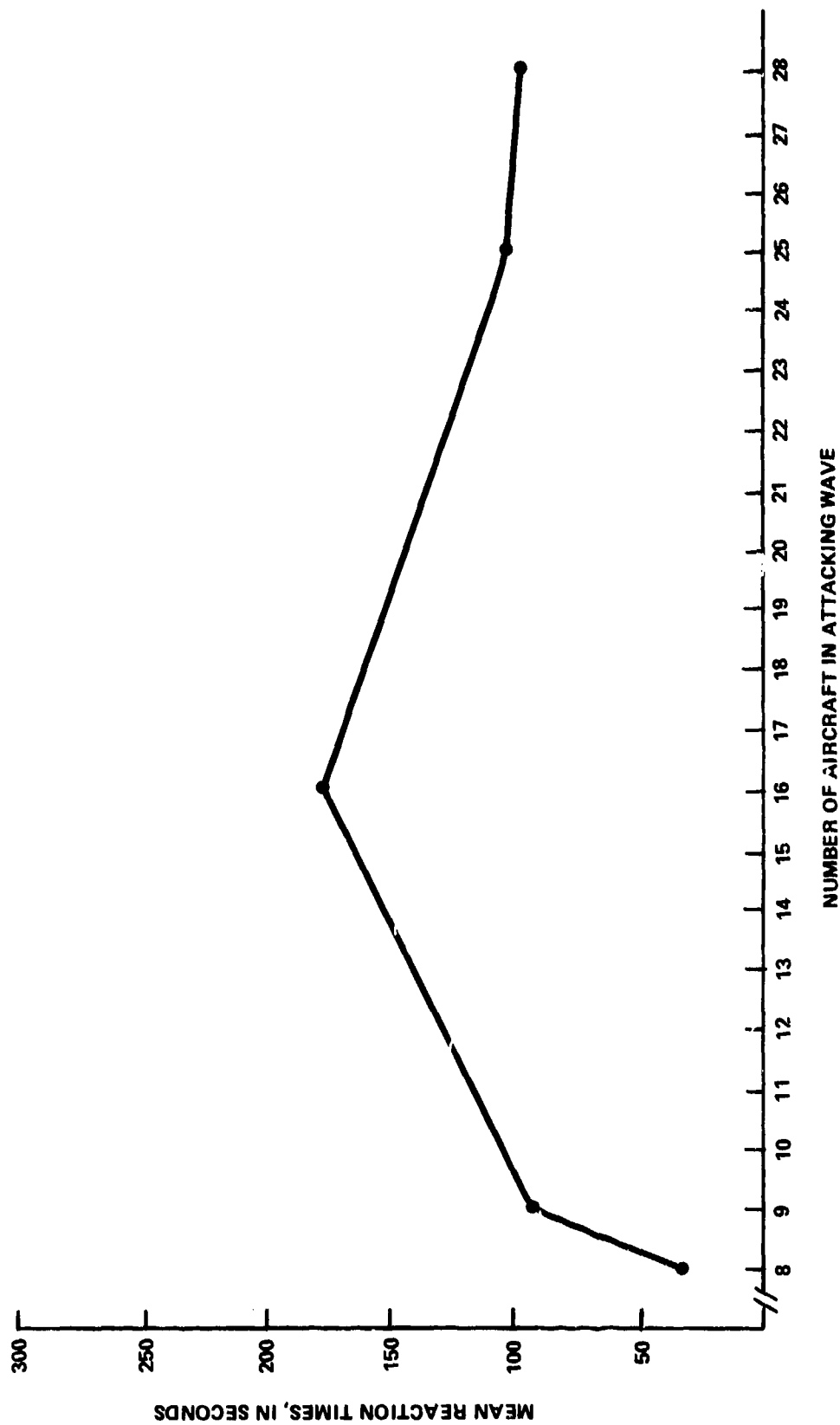
MEAN REACTION TIMES, IN SECONDS

15

Figure 3. Mean reaction times for WA as a function of six wave sizes.
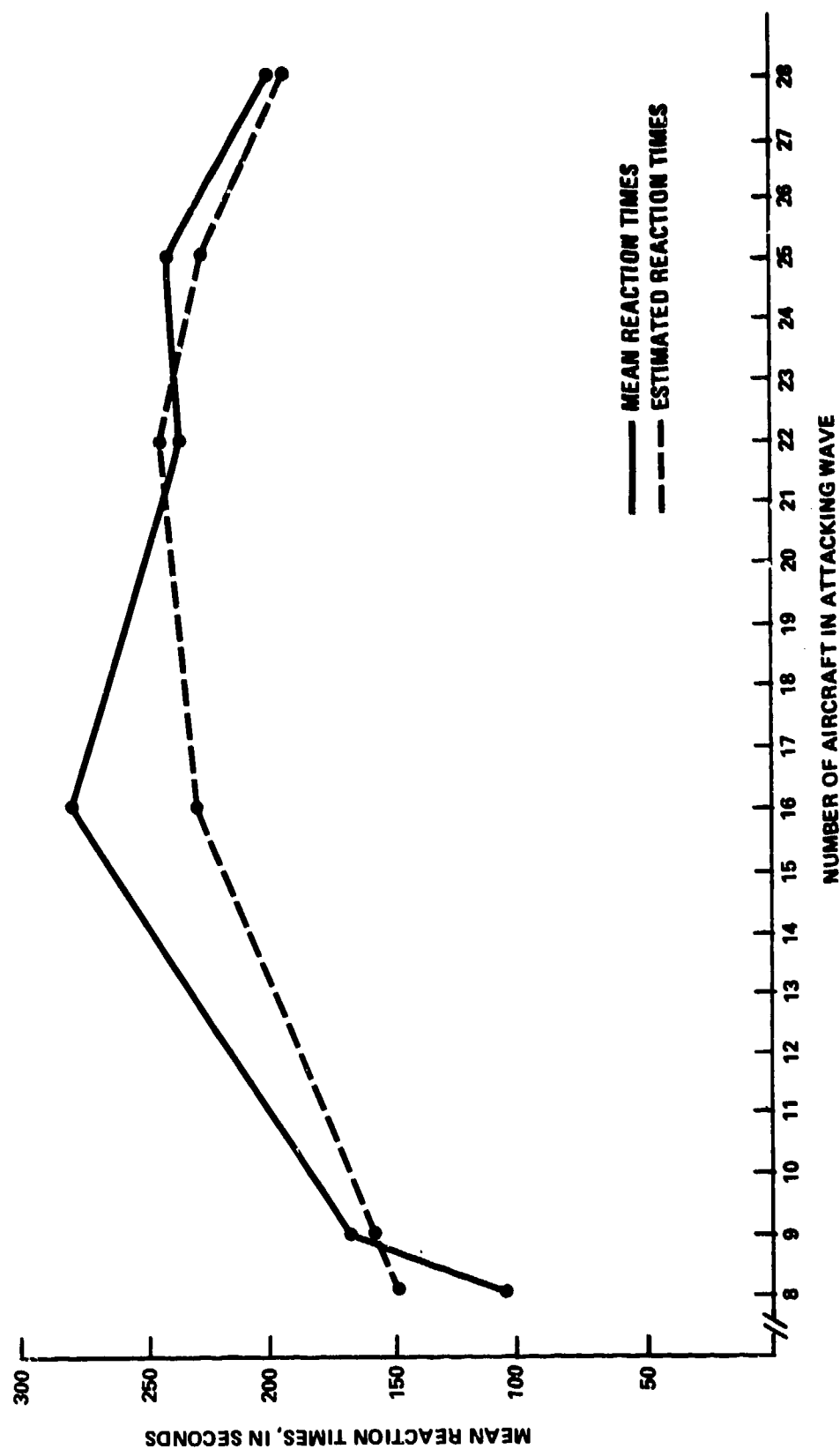
Figure 4. Mean reaction times and estimated reaction times for total reaction to a hostile aircraft as a function of wave size.
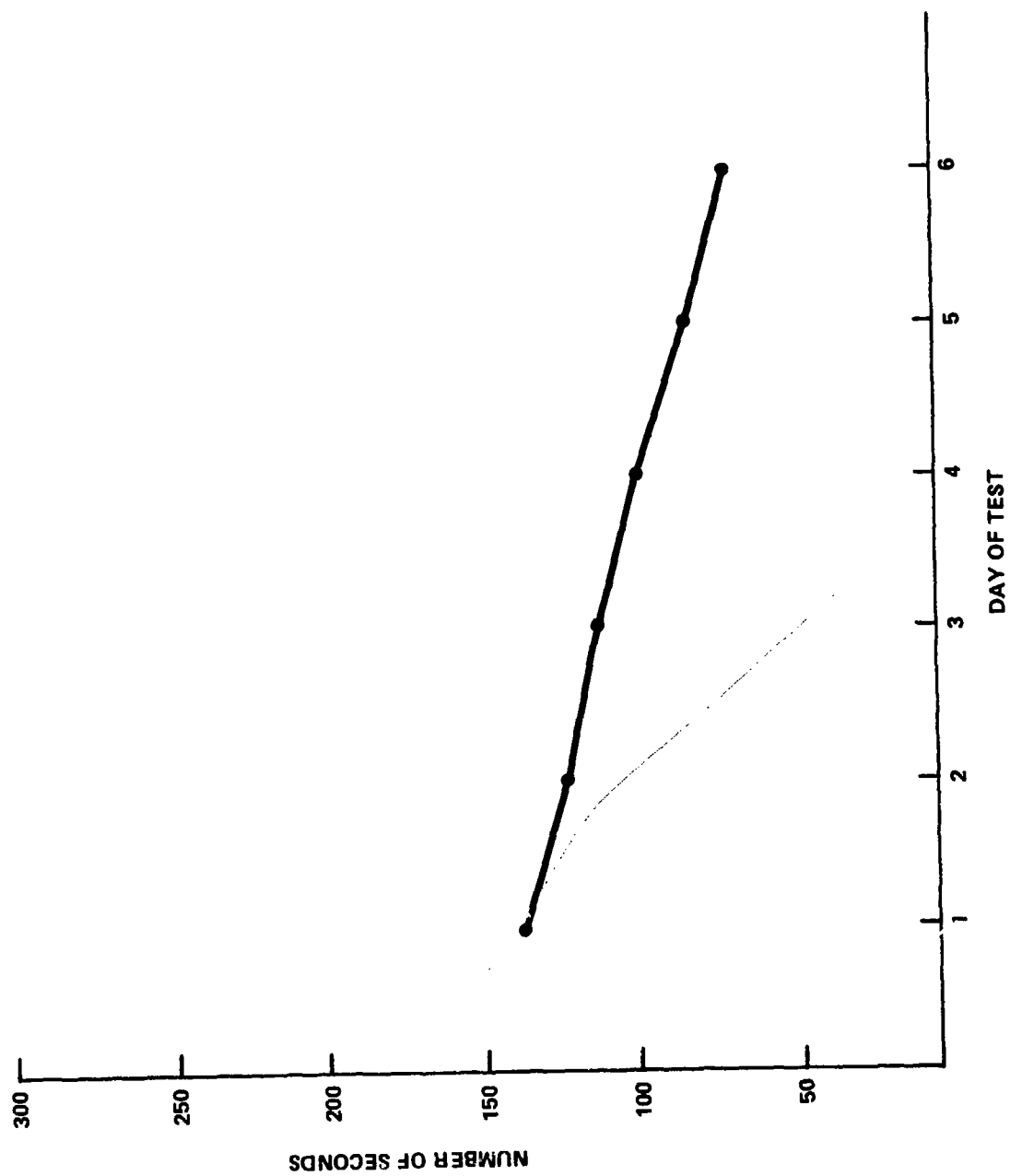
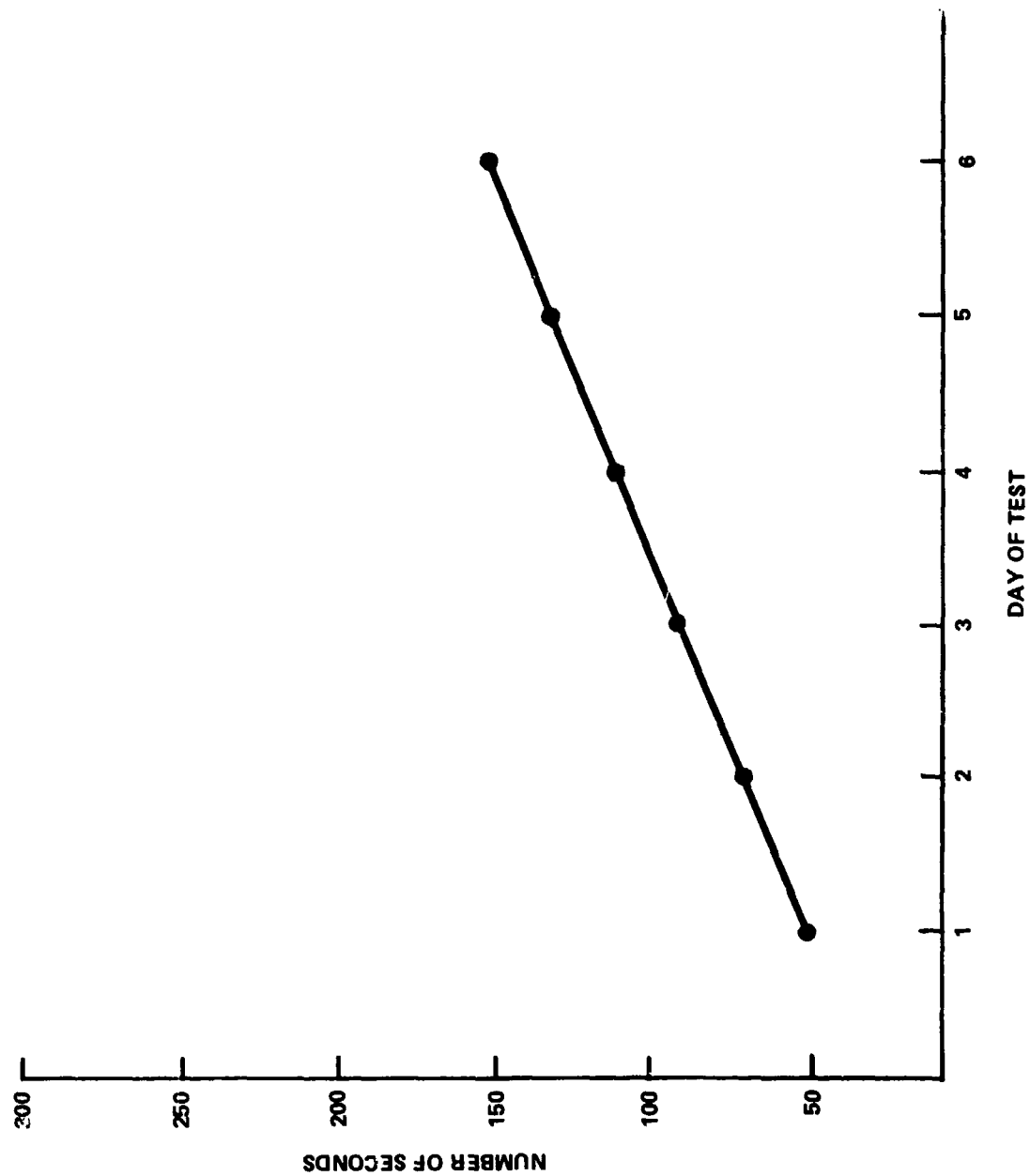Figure 5. Best fit estimated ID reaction times as a function of day of test.

18

Figure 6. Best fit estimate of WA reaction times as a function of day of test.

19

# APPENDIX

The techniques used in this report to determine predictive formulas involved a multiple linear regression program modified by Jorgensen to permit rapid generation of model vectors. A discussion of the statistical logic, model construction, and general programming methods is available in "An Introduction to Linear Models" (Ward & Jennings, 1973).

Briefly the technique involves solving for parameters in a theoretical equation previously defined by the experimenter to reflect specific psychological assumptions. This is done through a least squares fit of the equation parameters to raw or transformed data. The program then generates the standard beta weights and regression constant for that solution. The predictive power of the equation is specified by $M^2$, the squared multiple correlation coefficient. $M^2$ is mathematically equivalent to the percent of explained variation. Through the use of alternate equations, F ratios can be set up to compare various assumptions in terms of their explained variation. Analysis of variance and factorial analysis of covariance are two of the many possible model formulations which could be utilized within the regression framework.

Usually the most efficient strategy for finding optimal models consists of postulating a general all-encompassing equation which takes into account a linearly independent set of predictor variables based on conditions used in the experiment. The $M^2$ for this model serves as a maximum against which the predictive power of other simpler models is

21

judged. The simplest possible predictive model is the mean of the distributions. An F ratio formed between the general model and the mean model tests the usual null hypothesis for equality of means. By using the same technique with more complex models, F tests can be set up comparing various models to the general model and to each other. This is analogous to analysis of covariance. The pattern of significant F ratios as well as the $M^2$ efficiency of the models quickly points out the most efficient and parsimonious equations for a given set of assumptions and predictive power.

For example, in this experiment the three general models were all predictive equations taking into account raid tapes, low, medium, or high wave sizes, days, manning configuration, groups and fire units. A different general equation was generated for total, ID, and weapons assignment times. In this analysis four types of models were considered: orthogonal component models for each variable of interest (these are equivalent to a one-way analysis of variances for each variable), linear models (equivalent to simple linear regression fits), second and third order polynomial models (which investigated parabolic curves) and mixed models, such as a linear model going second order at a specific point. The following are examples of a general 12-element orthogonal model for total times, a model based on six wave sizes, a linear model, and a polynomial model:

$$\text{Time}_{(total)} = a_0 X_1 = a_1 S_2 + a_2 X_3 \ldots a_{11} X_{12}$$

$$\text{Time}_{(total)} = a_0 Y_1 + a_1 Y_2 + a_2 Y_3 Y_4 + a_4 Y_5 + a_5 Y_6$$

$$\text{Time}_{(total)}\ U+aW$$

$$\text{Time}_{(total)} = U+aW+a_1 W^2 + a_2 W^3$$

where $X_1 \ldots X_{12}$ are column vectors of 0's and 1's partitioning total data times into orthogonal sets as a function of such variables as days, ˙ ives or raid tapes.

$Y_1 \ldots Y_6$ are column vectors of 0's or 1's partitioning total times into sets for wave size one through 6, respectively.

U is a unit vector of 1's. W is a column vector containing the numbers one through 6 corresponding to the size of the wave.

$W^2$ is the direct product of W with itself.

a is a beta weight for the regression.

Though many models were considered and fit, only the most parsimonious and experimentaly meaningful are reported in this paper. The equations derived represent best fits for the available data. Their generalizability assumes the generalizability of the experimental situation to the combat usage of the AN/TSQ-73.

DISTRIBUTION

1 US ARMY CINCPAC SUPPORT GROUP  PERSONNEL DIVISION
1 HQDA  ATTN: PMAC
1 TAG/TAGCEN  ATTN: DAAG-ED
1 HQ, TCATA  ATTN: ATCAT-OP-Q
2 HQDA  RESEARCH AND STUDIES OFC
1 MILITARY OCCUPATIONAL DEVELOPMENT DIV  DAPC-MSR-O, RM 852C HOFFMAN BLDG 1
4 OASD (MRA AND L)
1 HQDA  ATTN: DAMO-RQR
1 HQ TCATA  TECHNICAL LIBRARY
1 HQDA  CHIEF, HUMAN RESOURCES DEVELOPMENT DIV
1 USRADCO, STC
1 HQDA  ATTN: DAMI-TSI
1 USA AVIATION SYSTEMS COMD  ATTN: DRSAV-ZDR
1 USA CORADCOM  ATTN: AMSEL-PA-RH
1 USA ARRADCOM  ATTN: ATFE-LO-AC
1 HEADQUARTERS, US MARINE CORPS  ATTN: CODE MPI-28
2 US ARMY EUROPE AND SEVENTH ARMY
1 1ST INFANTRY DIVISION AND FT. RILEY  ATTN: AAFZN-DPT-T
1 USA INTELLIGENCE AND SECURITY COMMAND  ATTN: IAOPS-TNG
2 HQ TRADOC  TECHNICAL LIBRARY
1 NAVAL TRAINING EQUIPMENT CEN  ATTN: TECHNICAL LIBRARY
1 MILITARY OCCUPATIONAL DEVELOPMENT DIV  ATTN: DAPC-MSP-S, RM 852C, HOFFMAN BLDG I
1 MILITARY OCCUPATIONAL DEVELOPMENT DIV  ATTN: DAPC-MSP-D, RM 852C, HOFFMAN BLDG I
1 MILITARY OCCUPATIONAL DEVELOPMENT DIV  ATTN: DAPC-MSP-T, RM 852C, HOFFMAN BLDG I
1 USAFACFA  CHIEF, ORGANIZATIONAL EFFECTIVENESS BRANCH
1 8TH INFANTRY DIVISION
1 HQDA  TANK FORCES MANAGEMENT OFC
1 NAVAL AIR SYSTEM COMMAND  ATTN: AIR-413F (CDR JAMES H. ASHBURN)
1 DCSOPS (DIST 4)  ATTN: DAMO-RQT + DAMO-RQC
1 123D USARCOM  RESERVE CENTER
1 FT. BENJAMIN HARRISON, IN  46216
1 DIRECTORATE OF ARMOR AVIATION  ATTN: ATSB-AAD
1 AVIATION DIVISION  ATTN: ATZK-DPT-AVN (UHIFS)
1 USA FORCES COMMAND  AFIN - DEPUTY C OF S FOR INTELLIGENCE
1 USA FORCES COMMAND  AFOP - DEPUTY CHIEF OF STAFF FOR OPERATIONS
1 US ARMY AIR DEFENSE
1 DIRECTORATE OF TRAINING  ATTN: ATZQ-T
1 DIRECTORATE OF COMBAT DEVELOPMENTS  ATTN: ATZA-D
1 HQDARCOM  MARINE CORPS LIAISON OFC
1 DEPARTMENT OF THE ARMY  US ARMY INTELLIGENCE + SECURITY COMMAND
1 US ARMY AGENCY FOR AVIATION SAFETY  ATTN: LIBRARIAN, BLDG 4905
1 USA MISSILE MATERIEL READINESS COMMAND  ATTN: DRSMI-NTN
1 ARTADS  ATTN: DRCPM-TDS-TD
1 USA FORCES COMMAND
1 PM TRADE  ATTN: DRCPM-TND-RE (DR. CRONHOLM)
1 US MILITARY DISTRICT OF WASHINGTON  OFC OF EQUAL OPPORTUNITY
1 NAVAL CIVILIAN PERSONNEL COMD  SOUTHERN FLD DIV
20 ARI LIAISON OFFICE
1 USACDEC  ATTN: ATEC-EX-E HUMAN FACTORS
1 USAFAGOS/TAC  SENIOR ARMY ADVISOR
1 INTER-UNIV SEMINAR ON ARMED FORCES + SOC
1 USA ELECTRONIC PROVING GROUND  ATTN: STEEP-MT-S
1 (OASD) (R AND D)  DEPUTY FOR SCIENCE AND TECHNOLOGY
1 OFC OF NAVAL RESEARCH  ATTN: CODE 455 (DR. MARTIN A. TOLCOTT)
1 AFHRL/TT
1 AFHRL/AS
2 AIR FORCE HUMAN RESOURCES LAB  ATTN: PE
1 FEDERAL AVIATION ADMINISTRATION  CENTRAL REGION LIBRARY, ACE-66
1 6570 AMRL/BH
1 6570 AMRL/HE
1 NAVAL PERSONNEL R AND D CENTER  COMMAND AND SUPPORT SYSTEMS

25

PRECEDING PAGE BLANK

1 NAVY PERSONNEL R AND D CENTER  ATTN: (CODE 308) EDMUND D. THOMAS
1 NAVY PERSONNEL R AND D CENTER  DIRECTOR OF PROGRAMS
1 NAVY PERSONNEL R AND D CENTER  ATTN: DR. B. RIMLAND
1 US ARMY AVN ENGINEERING FLIGHT ACTIVITY  ATTN: SAVTE-TD
2 OFC OF NAVAL RESEARCH  PERSONNEL AND TRAINING RESEARCH PROGRAMS
1 OFC OF NAVAL RESEARCH  ASST. DIRECTOR PERS + TRAINING RSCH PROGS
1 OFC OF NAVAL RESEARCH  PROJECT OFFICER, ENVIRONMENTAL PHYSIOLOGY
1 NAVAL AEROSPACE MEDICAL RSCH LAB  ATTN: (CODE L51)
1 BUREAU OF NAVAL PERSONNEL  SCIENTIFIC ADVISOR (PERS-OR)
1 NAVAL AEROSPACE MEDICAL RSCH LAB  AEROSPACE PSYCHOLOGY DEPARTMENT
1 USA TRADOC SYSTEMS ANALYSIS ACTIVITY  ATTN: ATAA-TCA
1 HEADQUARTERS, COAST GUARD  CHIEF, PSYCHOLOGICAL RSCH BR
1 USA RESEARCH AND TECHNOLOGY LAB  ATTN: DAVDL-AS
1 USA ENGINEER TOPOGRAPHIC LABS  ATTN: ETL-GSL
1 USA ENGINEER TOPOGRAPHIC LABS  ATTN: STINFO CENTER
1 USA ENGINEER TOPOGRAPHIC LABS  ATTN: ETL-TD-S
1 USA MOBILITY EQUIPMENT R AND D COMD  ATTN: DRDME-TQ
1 NIGHT VISION LAB  ATTN: DRSEL-NV-SDD
1 USA TRAINING BOARD
1 USA HUMAN ENGINEERING LAB
1 US HEL/USAAVNC  ATTN: DRXHE-FR (DR. HOFMANN)
1 USA MATERIEL SYSTEMS ANALYSIS ACTIVITY  ATTN: DRXSY-M
1 USA RESEARCH OFC  ATTN: F. W. MORTHLAND
1 NAFEC  HUMAN ENGINEERING BRANCH
1 BATTELLE-COLUMBUS LABORATORIES  TACTICAL TECHNICAL OFC
1 USA ARCTIC TEST CEN  ATTN: AMSTE-PL-TS
1 USA ARCTIC TEST CEN  ATTN: STEAC-PL-MI
1 USA CONCEPTS ANALYSIS AGCY  ATTN: MOCA-WG
1 USA CONCEPTS ANALYSIS AGCY  ATTN: MOCA-JF
1 HQ WRAIR  DIV OF NEUROPSYCHIATRY
1 USACACDA  ATTN: ATZLCA-CI-C
1 USACACDA  ATTN: ATZLCA-CI-M
1 USACACDA  ATTN: ATZLCA-CI-A
1 USACACDA  ATTN: ATZLCA-CA
1 USA ELECTRONIC WARFARE LAB  CHIEF, INTELLIGENCE MATER DEVEL + SUPP OFF
1 USA TROPIC TEST CENTER  ATTN: TECHNICAL LIBRARY
1 USA RSCH DEVEL + STANDARDIZA GP, U.K.
1 AFFDL/FGR (CDIC)
1 USA NATICK RESEARCH AND DEVELOPMENT COMMAND  CHIEF, BEHAV SCIENCES DIV, FOOD SCI LAB
1 OASD, E AND E (E AND LS)  MILITARY ASST FOR TNG + PERS TECHNOL
1 TRAJANA  ATTN: SAJS-OR
1 HQDA  ATTN: DASG-HG (LTG RICHARD E. HARTZELL)
1 NAVAL AIR SYSTEMS COMMAND  ATTN: AIR-5313
1 ECOM  ATTN: AMSEL-CT-O
1 USACDECEC  TECHNICAL LIBRARY
1 USAARL LIBRARY
1 HUMAN RESOURCES RSCH ORG (HUMRRO)  LIBRARY
1 SEVILLE RESEARCH CORPORATION
1 USA TRADOC SYSTEMS ANALYSIS ACTIVITY  ATTN: ATAA-SL (TECH LIBRARY)
1 UNIFORMED SERVICES UNIT OF THE HEALTH SCI  DEPARTMENT OF PSYCHIATRY
1 USA COMPUTER SYSTEMS COMMAND  ATTN: COMMAND TECHNICAL LIBRARY
1 HUMAN RESOURCES RSCH ORG (HUMRRO)
1 HUMRRO WESTERN LIBRARY
1 EUSTIS DIRECTORATE, USAAMRDL  TECHNICAL LIBRARY
1 RAND CORPORATION  ATTN: LIBRARY-MAITLAND
1 RAND CORPORATION  ATTN: LIBRARY D
1 FEDERAL AVIATION ADMINISTRATION  ATTN: CAMI LIBRARY ACC-44D1
1 NAFEC LIBRARY, ANA-64
1 GRONINGER LIBRARY  ATTN: ATZF-RS-L BLDG 1313
1 CENTER FOR NAVAL ANALYSIS
1 NAVAL HEALTH RSCH CEN  LIBRARY
1 NAVAL ELECTRONICS LAB  ATTN: RESEARCH LIBRARY

1 NAVAL PERSONNEL R AND D CEN LIBRARY  ATTN: CODE 9201L
1 AIR FORCE HUMAN RESOURCES LAB  ATTN: TSC
1 AIR FORCE HUMAN RESOURCES LAB  FLYING TRAINING DIVISION
1 HQ, FT. HUACHUCA  ATTN: TECH REF DIV
1 USA ACADEMY OF HEALTH SCIENCES  STIMSON LIBRARY (DOCUMENTS)
1 SCHOOL OF SYSTEMS AND LOGISTICS  ATTN: AFIT/LSCM
1 USAMERDC  TECHNICAL LIBRARY
1 DEPARTMENT OF THE NAVY  TRAINING ANALYSIS AND EVALUATION GP
1 NATIONAL CENTER FOR HEALTH STATISTICS  ATTN: M. DUPUY (PSYCHOLOGICAL ADVISOR)
1 USMA  DEPT OF BEHAVIORAL SCI AND LEADERSHIP
1 US NAVY  CNET SUPPORT RESEARCH LIBRARY
1 OLD DOMINION UNIVERSITY  PERFORMANCE ASSESSMENT LABORATORY
1 USA COMMAND AND GENERAL STAFF COLLEGE  ATTN: LIBRARY
1 USA TRANSPORTATION SCHOOL  USA TRANSP TECH INFO AND RSCH CEN
1 NASA HQ  ATTN: CODE RTE-6 (DR. MELVIN MONTEMERLO)
1 NMRDC  PROGRAM MANAGER FOR HUMAN PERFORMANCE
1 NAVAL MEDICAL R AND D COMMAND (44)
1 USA ADMINCEN  TECHNICAL RESEARCH BRANCH LIBRARY
2 HQDA  USA MED RSCH AND DEVEL COMMAND
1 USA FIELD ARTY HQ  ATTN: ATZR-HURT (KOLSTROM)
1 NAT CLEARINGHOUSE FOR MENTAL HEALTH INFO  PARKLAWN BLDG
1 U OF TEXAS  CEN FOR COMMUNICATION RSCH
1 INSTITUTE FOR DEFENSE ANALYSES
1 USA TRAINING SUPPORT CENTER  DEVEL SYSTEMS TNG + DEVICES DIRECTORATE
1 AFHRL TECHNOLOGY OFC (H)
1 PURDUE UNIV  DEPT OF PSYCHOLOGICAL SCIENCES
1 USA MOBILITY EQUIPMENT R AND D COMMAND  ATTN: DRDME-ZG
1 HQ, USA MDW  ATTN: ANPE-OE
1 DA US ARMY RETRAINING BDE  RESEARCH + EVALUATION DIR
1 USAF SCHOOL OF AEROSPACE MEDICINE  AEROMEDICAL LIBRARY (TSK-4)
1 US MILITARY ACADEMY LIBRARY
1 USA INTELLIGENCE CEN AND SCH  ATTN: SCHOOL LIBRARY
1 USA INTELLIGENCE CEN AND SCH  DEPT OF GROUND SENSORS
1 MARINE CORPS INSTITUTE
1 NAVAL SAFETY CENTER  ATTN: ROBERT A. ALKOV PH.D
1 USAAVNC AND FT. RUCKER  ATTN: ATZQ-ES
1 US ARMY AVN TNG LIBRARY  ATTN: CHIEF LIBRARIAN
1 USAAVNC  ATTN: ATZQ-D
1 US MILITARY ACADEMY  OFC OF MILITARY LEADERSHIP
1 US MILITARY ACADEMY  DIRECTOR OF INSTITUTIONAL RSCH
1 USA AIR DEFENSE SCHOOL  ATTN: ATSA-CD-MS
1 USAADS-LIBRARY-DOCUMENTS
1 USA AIR DEFENSE BOARD  ATTN: FILES REPOSITORY
1 USA INFANTRY BOARD  ATTN: ATZB-IB-TS-H
1 USA INTELLIGENCE CEN AND SCH  EDUCATIONAL ADVISOR
1 USA ORDNANCE CEN AND SCH  ATTN: ATSL-TEM-C
1 USA ARMOR SCHOOL  ATTN: ATSB-DT-TP
1 USA ARMOR CENTER  DIRECTORATE OF COMBAT DEVELOPMENTS
1 NAVAL POSTGRADUATE SCH  ATTN: DUDLEY KNOX LIBRARY (CODE 1424)
1 USA TRANSPORTATION SCHOOL  DEPUTY ASST. COMMANDANT EDUCA. TECHNOLOGY
1 USA SIGNAL SCHOOL AND FT. GORDON  ATTN: ATZH-ET
1 USA ARMOR SCHOOL  EVAL BRANCH, DIRECTORATE OF INSTRUCTION
1 CHIEF OF NAVAL EDUCATION AND TNG  ATTN: RAYBURN A. WILLIAMS (CODE 333)
1 USASIGS  STAFF AND FACULTY DEV AND ING DIV
1 HQ ATC/XPTD  TRAINING SYSTEMS DEVELOPMENT
1 USAISD  ATTN: ATSIE-DT-E
1 US ARMY ARMOR SCHOOL  DIRECTORATE OF TRAINING
1 USA QUARTERMASTER SCHOOL  DIRECTORATE OF TRAINING DEVELOPMENTS
1 US COAST GUARD ACADEMY  ATTN: CADET COUNSELOR (DICK SLIMAK)
1 USA TRANSPORTATION SCHOOL  DIRECTOR OF TRAINING
1 USA CHAPLAIN CENTER AND SCHOOL  ATTN: LIBRARIAN
1 USA INFANTRY SCHOOL LIBRARY  ATTN: MISS LIVINGSTON